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VII

GEOLOGY OF SHARKTOOTH HILL, KERN COUNTY, CALIFORNIA

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INTRODUCTION

In order to explain the geology of Sharktooth Hill and the strata from which were obtained the fossils which are to be described in the Academy's Proceedings, it has been necessary to give consideration to some of the surrounding area. The information has been accumulating through a period of years but even yet, it is believed, insufficient work has been done to warrant more than a general statement regarding some of the points discussed. Undoubtedly this will be looked upon as a deficiency by those who have pursued much more detailed studies in certain cases, but it is felt that the course followed has obviated any very serious errors.

So many people have contributed to make this report possible that it is impracticable to mention all. However the friendly spirit of cooperation which has been invariably shown is most deeply appreciated.

LOCATION

Sharktooth Hill is located on the north side of Kern River in Sec. 25, T. 28 S., R. 28 E., M. D. M., Kern County, California. This is about seven miles northeast of Bakersfield. The hill is a somewhat isolated prominence set back from the river about one-fourth mile. The elevation is given as 643 feet on the Caliente sheet of the U. S. Geological Survey's topographic map, but the hill is not named thereon. The road to the Round Mountain oil field passes to the south.

The section on which Sharktooth Hill is located belongs to the Southern Pacific Land Company.

HISTORY

The locality has long been known for the great numbers of teeth of sharks which might be picked up from the surface of the slopes of the hill. Large collections of these are in numerous museums. Several species of sharks are represented and the size of the teeth varies from a length of 10 millimeters in *Gyracc* to over 100 millimeters in the giant *Carcharodon.*

Much study has been devoted to these teeth in the past by Louis Agassiz, David Starr Jordan and his associates; a list of important publications is given below.[1]

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[1] Agassiz, L. Notice of fossil fishes found in California by W. P. Blake. Amer. Jour. Sci. & Arts, ser. 2, vol. 21, 1856, pp. 272-275. Notice of the fossil fishes. Explorations and surveys for a railroad from the Mississippi River to the Pacific Ocean, vol. 5, 1857; Geological Report by William P. Blake, Appendix, Article 1, pp. 313-316, pl. 1.

Jordan, D. S. The fossil fishes of California with supplementary notes on other species of extinct fishes. Univ. Calif. Publ. Bull. Dept. Geol. vol. 5, no. 7, 1907, pp. 95-144, pls. 11, 12, 33 text figs.

Leriche, Maurice. Observations sur les Squales Néogènes de la Californie. Annal. Soc. Geol. du Nord, vol. 36, 1908, pp. 302-306.

Jordan, D. S. & C. H. Beal. Supplementary notes on fossil sharks. Univ. Calif. Publ. Bull. Dept. Geol. vol. 7, no. 11, 1913, pp. 243-256, 8 text figs.

Jordan, D. S. & J. Z. Gilbert. Fossil fishes of the (Miocene) Monterey formations of Southern California. Leland Stanford, Jr. Univ. Publ. Univ. Ser., in "Fossil fishes of southern California," art. 2, 1919, pp. 13-60, pls. 1-31.

Jordan, D. S. Some sharks' teeth from the California Pliocene. Amer. Jour. Sci. ser. 5, vol. 3, 1922, pp. 338-342, 9 text figs.

Jordan, D. S. & H. Hannibal. Fossil sharks and rays of the Pacific Slope of North America. Bull. Southern Calif. Acad. Sci. vol. 22, pt. 2, 1923, pp. 27-63, pls. 1-14.

Leriche, M. Les Poissons Néogènes de la Belgique. Mem. Mus. Roy. d'Hist. Nat. Belgique, no. 32, 1926, pp. 365-472, pl. 28-41.

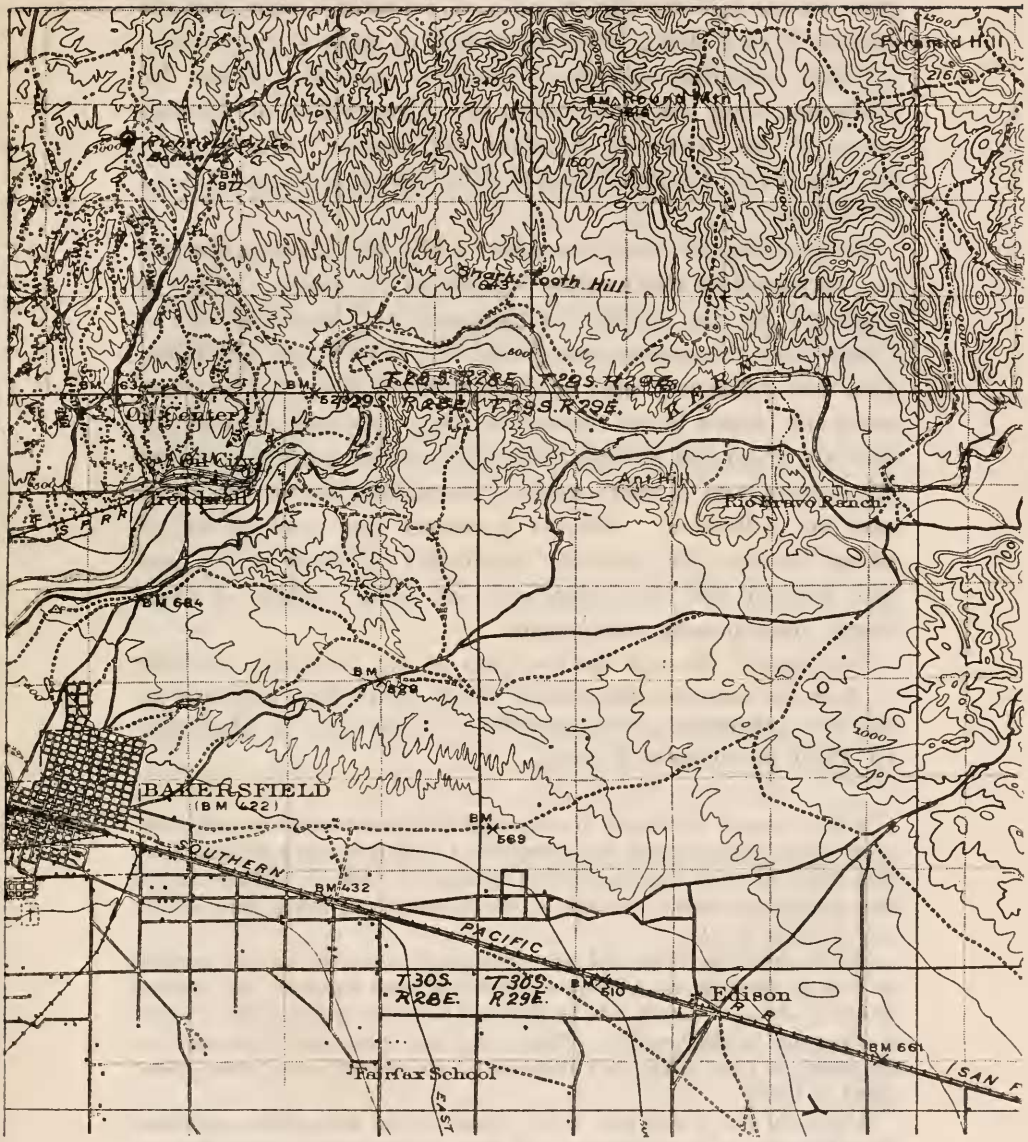

Fig. 1. Part of U. S. Geological Survey, Topographic Map, Caliente Sheet, Kern County, California, showing Sharktooth Hill and other prominent points.

No record has been kept of the many visitors who have gone to the hill for the purpose of collecting teeth, but the number is very large. One of the first to make a fairly representative scientific collection, however, was Mr. Frank M. Anderson, long associated with the Department of Paleontology of the California Academy of Sciences. His material was studied by Jordan & Beal in their report on fossil fishes of California.

Before that, that is in November 1909, Mr. Charles Morrice was attracted to the locality because of its fossils. He was employed by the Pacific Oil Company and stationed at Oil Center near the eastern margin of the Kern River Oil Field. This was sufficiently near to Sharktooth Hill so that he could spend his leisure hours there collecting. He soon located the stratum which had produced the teeth found weathered out on the surface and a vast number, beautifully preserved, came into his collection. Always generous and considerate of others' wishes, Mr. Morrice distributed his finds widely and they formed the very foundation of some studies of fossil sharks subsequently undertaken.

Fortunately, through the kindness of Mr. Morrice, I am able to give his own account of his many years as a collector of marine vertebrates at this locality. Under date of December 10, 1929, he wrote as follows:

"I first became interested in collecting fossils about November, 1909. Some of my acquaintances, observing that I took long excursions on Sundays asked me if I had ever visited Sharktooth Hill. I had not and it took me several weeks to locate it. Once found, my hobby became collecting sharks' teeth.

"All of the teeth which had been gathered at the place up to this time, as well as those in the collection which had been made by Mr. Barker on his ranch on the south side of the river had been more or less leached by exposure to the weather. This is evident from the illustrations in the paper on fossil fishes of California by Dr. David Starr Jordan, published in 1907.[2]

"I carried, first a pick and then a shovel to the hill, which was about five miles east of my residence, and made an excavation about four or five feet deep. This resulted in securing many beautifully preserved

[2] Jordan, D. S. Univ. Calif. Publ. Bull. Dept. Geol. vol. 5, no. 7, 1907, pp. 95-144, pls. 11, 12.

specimens in a fine, hard silt or mud which effectively protected the enamel of the teeth.

"In about six months I had gathered several hundred specimens and having become acquainted with Mr. F. M. Anderson I showed them to him. He suggested that I write to Dr. Jordan for a copy of his paper referred to above, in order that I might be able to classify the collection. This I did but my letter was lost, much to my chagrin. Some months later I told Mr. Anderson of my failure to receive the copy of the paper and he promised to send me his own, which he did. When Dr. Jordan finally learned of my efforts and desire for literature on the subject he very courteously sent me an autographed copy.

"By early 1912 my collection amounted to about 2,000 specimens, including bones and teeth of the sea lion, later named *Allodesmis kernensis* by Dr. Kellogg. Upon consulting Mr. Anderson as to the disposition of the material, he suggested three institutions worthy of receiving it, namely: Stanford University, University of California and California Academy of Sciences.

"After due consideration I sent the entire collection to Mr. Anderson for the California Academy of Sciences for such disposition as might seem best. It was suggested that only duplicates be given to other institutions.

"In about six months more I had gathered together about 1,500 additional specimens. These I sent to Dr. Jordan for Stanford University and they, with the collection already presented to the Academy, formed the basis of the good Doctors' 'Supplementary notes on fossil sharks' published in 1913.[3]

"My next collection of over 1,000 specimens was sent to Dr. J. C. Merriam for the University of California. Other collections made later were sent to: University of Neveda; University of Wisconsin; Southern California Academy of Sciences; Universities of Lille, France; Brussels, Belgium; Aberdeen, Scotland; and to the High School and Chamber of Commerce of Bakersfield, California.

"During the summer of 1922 Dr. Remington Kellogg and Dr. Bruce L. Clark of the University of California, accompanied by several other gentlemen, visited me and we made an excursion to the Sharktooth Hill deposit. In a short time we uncovered enough bones to arouse their interest. At Dr. Kellogg's request I began sending fossil bones to him at the U. S. National Museum and this continued until 1924 when the skull of *Aulophyseter morricei* was shipped.

"In the fall of 1924 through the interest of the California Academy of Sciences, Mr. Tom Harbert was employed during October, November and December and the large collection being described by Dr. Kellogg was then obtained.

"Dr. Jordan visited me in 1923 and again in 1924; large collections were given him on each occasion. Some of these specimens were used

[3] Jordan, D. S. & C. H. Beal. Univ. Calif. Publ. Dept. Geol. vol. 7, no. 11, 1913, pp. 243-256, 8 text figs.

in the paper published by the Southern California Academy of Sciences in 1923 by him and Harold Hannibal.[4]

"Along with the teeth of sharks there were many ear bones of dolphins and bones of seals and sea lions which Dr. Jordan transmitted to Dr. Kellogg.

"After every shipment of bones to Dr. Kellogg he wrote very interesting accounts of the 'finds'. These consisted of bones of dophins, porpoises, seals, sea lions, whales and sea cows. His letters were so inspiring that it was indeed a pleasure to have worked with him. My greatest regret is that I did not make his acquaintance at an earlier date so that many specimens of bones, cast aside in the search for sharks' teeth, might have been preserved."

Previous to Dr. Kellogg's visit in 1922, Mr. Morrice had already saved a considerable number of bones and teeth of what appeared to him to have belonged to one species of animal. These, together with material obtained by the two collectors together formed the basis for Kellogg's description of the sea lion, *Allodesmis kernensis*.[5]

It became evident from the work done up to 1924 that the stratum exposed on Sharktooth Hill contained an enormous number of bones and teeth of marine vertebrate animals. Remains of whales and sharks were particularly abundant and the sperm whale *Aulophyseter morricei* was described from the collection sent to the National Museum.[5a]

Up to that time no reasonable hypothesis had been evolved to account for the anomalous disassociation of all skeletal elements of the animals and the fragmentary nature of many of the bones. The California Academy of Sciences entered into correspondence with Dr. Kellogg and Dr. John C. Merriam of the Carnegie Institution of Washington on the subject and conferences were had with Mr. Morrice, Mr. M. E. Lombardi, then Vice President of the Pacific Oil Company and with Messrs. J. E. Taff and E. G. Gaylord, Geologists for the company. After due consideration of all interests and factors it

[4] Jordan, D. S. & H. Hannibal. Bull. Southern Calif. Acad. Sci. vol. 22, pt. 2, 1923, pp. 27-63, pls. 1-14.

[5] Kellogg, R. Univ. Calif. Publ. Geol. Sci. vol. 13, no. 4, 1922, pp. 26-114, 19 text figs.

[5a] Kellogg, R. Study of the skull of a fossil sperm-whale from the Temblor Miocene of southern California. Carnegie Inst. Washington, Publ. no. 346, 1927, pp. 1-24, pls. 1-9.

was decided early in 1924 that the Academy should undertake some more extensive excavations than had theretofore been attempted.

The field work was under the immediate supervision of Mr. Morrice whose services were gratituous. Mr. Tom Harbert was employed as assistant continuously for the last three months of 1924, and it was during this period that the greater part of the collection to be reported upon by Dr. Kellogg was obtained. This report amply illustrates the wealth of material in the Sharktooth Hill deposit. The author has commented at times on the unfortunate disassociation of the skeletons and the fragmental nature of many of the bones. The preservation is normally very good, but how to account for broken pieces of limb bones and ribs in close proximity to vertebra and other delicate bones is a problem for which no satisfactory solution has yet been suggested.

Geologic Section

The total thickness of sediment exposed on Sharktooth Hill is about 200 feet. The strata dip to the southwest at low angles, the maximum being about 6°. The top of the hill is composed of unconsolidated sands and gravels belonging to the Kern River Series with an important unconformity at the base. This unconformity is not characterized by any very noticeable discordance in dip or strike of the strata, but it is known that it marks the absence of several thousand feet of sediment. On Sharktooth Hill the contact is not well exposed but the upper layer of the Temblor outcrops as a consolidated sandstone containing many fossil mollusca. This outcrop is within 50 feet of the top of the hill on the southeast side.

Between the shell layer and the bone bed there is a zone of 30 feet of loosely consolidated sands and sandy shales not well exposed. The bone bearing layer itself is about four feet thick with the bones and teeth most abundant near the bottom. The matrix is loosely consolidated and poorly sorted sand with occasional small pebbles. The bone and shell beds

together constitute the type locality of zone "C" of F. M. Anderson.[6]

Below the bone bearing stratum there is a zone of brown sandy shales about 30 feet thick which have contained abundant foraminifera, but on this outcrop the tests have been dissolved away leaving poor impressions. The presence of the large, characteristic *Valvulineria* of this part of the Miocene is easily determined, however, with a hand lens.

The diatomite from which the flora to be described in a succeeding paper was obtained, outcrops immediately below these sandy shales and extends downward to the base of the hill. All of the diatom bearing material is somewhat impure, acidic ash being the chief mineral constituent. Some of the layers are light and "punky" and all of them weather to a pale brown color. The total thickness exposed is 75 to 100 feet. The identification of this horizon over wide areas has been dealt with in the paper describing the flora.

The total exposure of strata on Sharktooth Hill is not sufficient to permit a general statement pertaining to the entire Miocene section of this area, but it so happens that several wells have been drilled nearby. These have been cored almost continuously and furnish extremely reliable sectional data. This will be presented in some detail, but before doing so it will be desirable to comment on the geographic extent of the outcropping and related beds.

The shell layer mentioned as occurring at the top of the section is of exceedingly limited distribution. It has not certainly been identified elsewhere by me except on a hill south of Kern River and just west of the lower portion of Cottonwood Creek. The presence of *Turritella ocoyana* Conrad is sufficient evidence to indicate the Temblor age of the material.

In contrast to this the bone bearing stratum is of very wide distribution on the east side of the valley and has been identified in many outcrops. The southernmost exposure lies far to the south of Sharktooth Hill on the divide between the Caliente Creek and Kern River drainage. Sharks' teeth collected there by F. M. Anderson and Harold Hannibal were

[6] Anderson, F. M. The Neocene deposits of Kern River, California, and the Temblor Basin. Proc. Calif. Acad. Sci. ser. 4, vol. 3, 1911, p. 85.

described by Jordan & Hannibal, the locality being usually indicated as "Bena," a station on the Southern Pacific Railroad nearby.[7]

Traces of bones and teeth may also be found on the old Barker Ranch on the south side of Kern River in Secs. 5, 6, T. 29 S., R. 28 E. The diatom horizon outcrops at the river and the structure is so complicated by faulting that the thickness between it and the bone layer could not be determined although it seemed to be greater than on Sharktooth Hill.

In a northwesterly direction from the hill the bone layer can be traced by outcrops far to the north, to the old "Fullers Earth Mine" on Granite Creek three miles north of Poso Creek. The matrix at this point is more ashy and less sandy than at Sharktooth Hill and the bones and teeth are found through a vertical thickness of at least 30 feet. However, they are much more abundant in the lower portion of the exposure.

Another outcrop has been brought to the surface by faulting in a branch of Granite Creek coming from the northwest. This is in the northeast corner of Sec. 28, T. 27 S., R. 28 E., M. D. M., and probably is the locality from which Blake made a collection of sharks' teeth during the progress of the Pacific Railroad Survey.[8]

The sandy shales mentioned as lying between the bones and diatomite in the Sharktooth Hill exposure form a part of what has come to be recognized by all working geologists of the region as the *"Valvulineria* zone." Outcrops are numerous and usually unmistakable although the fossil from which the zone takes its name has a vertical range of probably 500 feet. In fact it extends upward into the base of the Montery at the type locality near the town of that name. The association of foraminifera found at the two localities has been the means of determining that the top of the Temblor in this Kern River section is very nearly the stratigraphic equivalent of the base of the type Monterey. The difference, if any, cannot amount to more than a few hundred feet of strata. It is extremely probable that the diastrophism which caused the termination

[7] Jordan, D. S. & H. Hannibal. Bull. So. Calif. Acad. Sci. vol. 22, pt. 2, 1923, pp. 27-63.

[8] This collection was described by Louis Agassiz in 1856 and 1857; see footnote no. 1.

of marine sedimentation on the east side of the San Joaquin Valley initiated the same in the Monterey area. In many localities where sedimentation was continuous through the period it becomes impossible to draw a sharp line of contact between the Temblor and Monterey. This unfortunate circumstance has resulted in the identification of a group of strata as the older formation by some paleontologists while others have referred the same beds to the younger. The situation is complicated in other ways and requires very careful analysis.

In the immediate vicinity of Sharktooth Hill, exposures are lacking which furnish information on the strata directly below the zone of diatomite at the base of the hill. East of the hill, which normally would be down deeper in the section there is a major fault, striking in a general north-south direction. The west side of this fault is upthrown several hundred feet; to the east, therefore, for a considerable distance, the formations are marked by Kern River Series and terrace deposits.

At the point shown on the map near the letter "K" of "Kern" in the northeast corner of Sec. 5, T. 29 S., R. 28 E., there is a prominent exposure of gray, loosely consolidated sandstone charged with beautifully preserved molluscan fossils. The locality has furnished many striking new species, described chiefly by Anderson & Martin.[9] The bed became "zone B" of the first author.[10]

The fauna of this zone has become very well known because of the excellent preservation of the fossils and it is often referred to as the *Agasoma barkerianum* zone of the Temblor. Conrad[11] described the first fossils from it in 1855 chiefly from sketches of casts and molds made by W. P. Blake at an unknown locality probably on Poso Creek a few miles to the north. Cooper[12] in 1894 added to the list of species, from

[9] Anderson, F. M. & B. Martin. Proc. Calif. Acad. Sci. ser. 4, vol. 4, 1914, pp. 15-112, pls. 1-10.

[10] Anderson, F. M. Proc. Calif. Acad. Sci. ser. 4. vol. 3, 1911, p. 85.

[11] Conrad, T. A. Pacific R. R. Repts. House Doc. 129, 33rd Cong. 1855, pp. 18-20; Quarto Rept. vol. 5, 1857, pp. 328-329, pls. 7-9.

[12] Cooper, J. G. Catalogue of California Fossils. Calif. State Mining Bureau, Bull. 4, 1894, pp. 53-54.

material collected across the river to the south of the zone B locality, on the old Barker Ranch.

The zone B locality is far enough to the east of Sharktooth Hill so that if the horizontal distance be projected with the dip of the beds there is an apparent vertical distance of approximately 500 feet between it and zone C; this figure was computed by F. M. Anderson in defining the zones, but the intervening faulting was not noted. Actually the two zones are not widely separated vertically. They are really sandy phases of the upper part of the Temblor of this area, and in no cases are they of wide areal extent in the region. (Reference is made only to that part of "zone C" at the top which contains the fossil mollusca.) The zones are too indefinite and inconstant in lateral distribution to answer the needs of present day stratigraphy and have been practically replaced for map making purposes by the much more persistent zones of micro-fossils. Identifiable molluscan fossils are rarely found in the collections made in drilling wells and it is these which have furnished the most complete and reliable information on the geology of region.

Below these molluscan bearing sands of the upper Temblor there is a succession of sandy shales carrying an abundance of foraminifera. They might all be classed in the general term "*Valvulineria* zone" but differences in the succession of strata show changes in the assemblage of species and the abundance or rarity of particular species; for this reason more or less subdivision is practicable but the details vary among the different workers. This subdivision will not here be discussed because it should accompany a detailed discussion of the foraminifera which is yet to be made.

This zone of foraminifera-bearing shales is followed by several hundred feet of light gray ashy shales, practically barren of fossils except fish scales and bones. The thickness probably varies between 1000 and 1500 feet in most cases. Occasional shells are scattered through and foraminifera are found sparingly at several places, thus affording a means for zonal subdivision in some of the most detailed work which has been undertaken. Lithologically there are changes embodying clay, silt, fine sandy shale, fine sand, ashy shale and

occasionally hard calcareous lenses. These variations are inconstant in distribution, and it is not believed that any of them, taken alone are now used for correlation purposes.

Toward the base of the ashy shale series, however, this material takes on a peculiar form which can often be recognized. The background is pale pearl-gray ashy shale and disseminated throughout there are irregular thin black or dark gray lines, extending in every direction, abundantly but not crowded. The appearance has suggested the name "hair shale zone." The layers of material having this character are limited in thickness and seem to be absent in some cases. However, the zone is accompanied by a very striking assemblage of foraminifera found widely distributed in this region and in many other places in California, Oregon and Washington. The zone is approximately 250 to 275 feet thick. It outcrops on Adobe Creek (a north branch of Poso Creek) where a major fault has lifted the strata on the east several hundred feet.

Immediately below this hair shale zone about 250 to 300 feet of ashy and sandy shales carry a fauna of foraminifera in which *Siphogenerina* is dominant. This, likewise, is widely distributed in the west although I do not know that it outcrops in the Kern River Region.

From this point on down to the base of the Temblor the sediments are predominantly sandy with some strata of gravel and conglomerate. The thickness is extremely variable, as might be expected, but an average of 600 feet suggested for the area may not be far wrong.

Fossils are notably scarce in the cores taken from wells; enough mollusca have been found, however, to identify the zone definitely with the sandstone strata which outcrop on Pyramid Hill along the granite contact at the east side of the valley. The hill is in Sec. 14, T. 28 S., R. 29 E. and about five miles east northeast of Sharktooth Hill. A large and striking assemblage of fossil mollusca has been obtained on Pyramid Hill and, being near the base of the Temblor section, the locality was designated "zone A" by F. M. Anderson.[13]

[13] Anderson, F. M. Proc. Calif. Acad. Sci. ser. 4, vol. 3, 1911, p. 85.

The same zone is found at Comanche Point at the south end of the valley and has been tentatively identified at some places on the west side.

The Temblor rests on an uneven surface of a series of green, red and blue, often mottled, clays, sandy shales, sands and gravels. These have much the appearance of being of continental origin. They are pratically non-fossil bearing and have come to bear the name "Walker formation" because there is a limited exposure in Walker Basin Creek in the southeast corner of the valley. At that point the shales contain sparingly, fossil land shells but these have not yet helped in determining the age of the formation. Some have thought them to be the equivalent of the Sespe formation, but they may be a phase of the Vaqueros Miocene. There are limited outcrops of the material on Pyramid Hill and to the north as far as the point where Granite Creek issues upon the valley plain. Excellent exposures are found at Comanche Point beneath the Temblor. At none of these places can an adequate conception of thickness be obtained and data derived from the few wells which have penetrated the formation are equally misleading. For the sake of record, however, it should be stated that in Sec. 4, T. 26 S., R. 27 E., M. D. M., the thickness of the Walker was 172 feet.

In most of the wells which have gone through the Walker clays and sands, granite has been encountered. But in one limited area which includes Secs. 16 and 22, T. 26 S., R. 28 E., M. D. M., the basement rock was slate or shistose rock which possessed all the physical characters of the Mariposa, found outcropping far to the north.

The areal geology of the Kern River Region is now known to be characterized by an extremely complicated system of faults. These have probably resulted from major and minor fractures in the underlying granite. An idea of their extent and general character can probably best be obtained from a study of the granite itself as exposed a few miles to the eastward where joint planes and faults of some significance are extremely numerous and highly irregular in trend. And the locations where some of the more obvious breaks occur in the

valley sediments are very well described and shown on a map in a late report by Mr. Leo S. Fox.[14]

The following sections of two representative and thoroughly sampled wells drilled in the vicinity of Sharktooth Hill are offered to support the statements already made. I am deeply indebted to my associate, Mr. C. C. Church, for the preparation of these sections and much other assistance through a period of years.

Two formation names have been omitted from these sections which some geologists would indicate. These are Chanac and Santa Margarita. The first has been applied to a certain zone of material which is lithologically very much like parts of the Kern River series but it lies below some marine shales and sands which appear to be Etchegoin Pliocene. The name was originally given to a certain landlaid deposit at the south end of the valley from which imperfectly preserved vertebrate fossils have been collected. The evidence to support the theory that the sediments found in the wells about Bakersfield are equivalent in age to the type locality is very meager and is too insecure at this time, it seems to me, to justify the transplantation of the name so far.

The basis for recognizing Santa Margarita (upper Miocene) in the wells of the Kern River District is likewise extremely unsafe. Below the clays and sands called Chanac there is found a marine zone of sediments containing some foraminifera which are different from typical upper Temblor and upper Etchegoin and it is to this zone that the name has been applied. Some competent geologists believe that the evidence indicates an interfingering or overlapping of marine and landlaid material early in the Pliocene because the distinctions have been proved to disappear farther out in the valley from the eastern shore line. The fossils found in the so-called Santa Margarita of the wells are not sufficient for this determination because no foraminifera have been found at the type locality of that formation; at least none have been reported.

[14] Fox, Leo S. Structural features of the east side of the San Joaquin Valley, California. Bull. Amer. Assoc. Petrol. Geol. vol. 13, no. 2, 1929, pp. 101-108, map fig. 1.

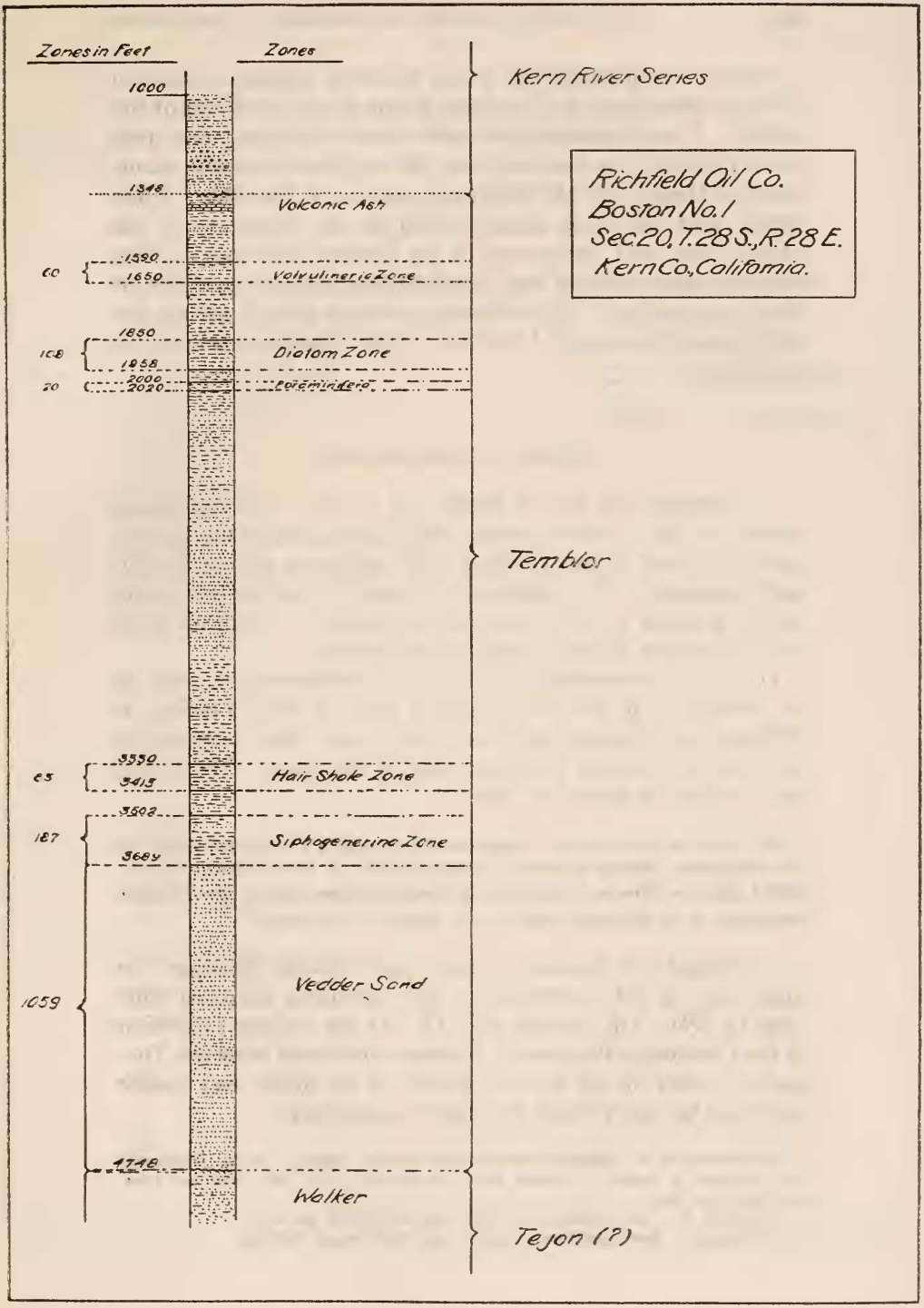

Fig. 2. Section shown in drilling Richfield Oil Company Well, Boston No. 1, near Sharktooth Hill.

Part of the difficulty has arisen from the supposed existence of Santa Margarita at Comanche Point at the south end of the valley. A very considerable collection of mollusca has been made there for the Academy and this has been critically examined by Messrs. F. M. Anderson and L. G. Hertlein. They advise that the large oyster found in the collection is not *Ostrea titan* and the pecten is not *Pecten crassicardo*. The original determination was based on the supposed presence of these two species. The collection contains several species not yet known from upper Miocene or later deposits any place in California.

General Correlations

An attempt will not be made here to give a chronological account of the various efforts which have been made to correlate this part of the Temblor with sediments widely distributed elsewhere. It is believed the needs of the present study will be fulfilled by presenting the conclusions reached by those who have most recently taken up the subject.

Dr. W. P. Woodring[15] in 1928 in a comprehensive study of the Mollusca of Bowden, Jamaica gave a large number of Miocene correlations and these have much wider application than can be inferred from the title of the paper. Regarding the Temblor he stated (p. 98):

> "By means of this indirect comparison and relying for the most part on the admittedly slender evidence of one phylum of Turritellas it is concluded that the Bowden formation is about the same age as the Temblor formation, or as the upper part of the Temblor formation."

He placed the Bowden in the upper Middle Miocene, the equivalent of the Tortonian of the European standard time scale (p. 39). On another page (p. 94) the Calvert formation of the Chespeake Bay area is likewise correlated with the Tortonian, chiefly on the basis of studies of the plants and marine mammals by Berry[16] and Kellogg[17] respectively.

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[15] Woodring, W. P. Miocene mollusks from Bowden, Jamaica. Pt. 2. Gastropods and discussion of results. Carnegie Inst. Washington, Publ. 385, 1928, pp. 1-564, pls. 1-40, 2 text figs.

[16] Berry, E. W. U. S. Geol. Surv. Prof. Ppr. 98-F, 1916, pp. 61-70.

[17] Kellogg, R. Bull. Geol. Soc. America, vol. 35, 1924, pp. 763-764.

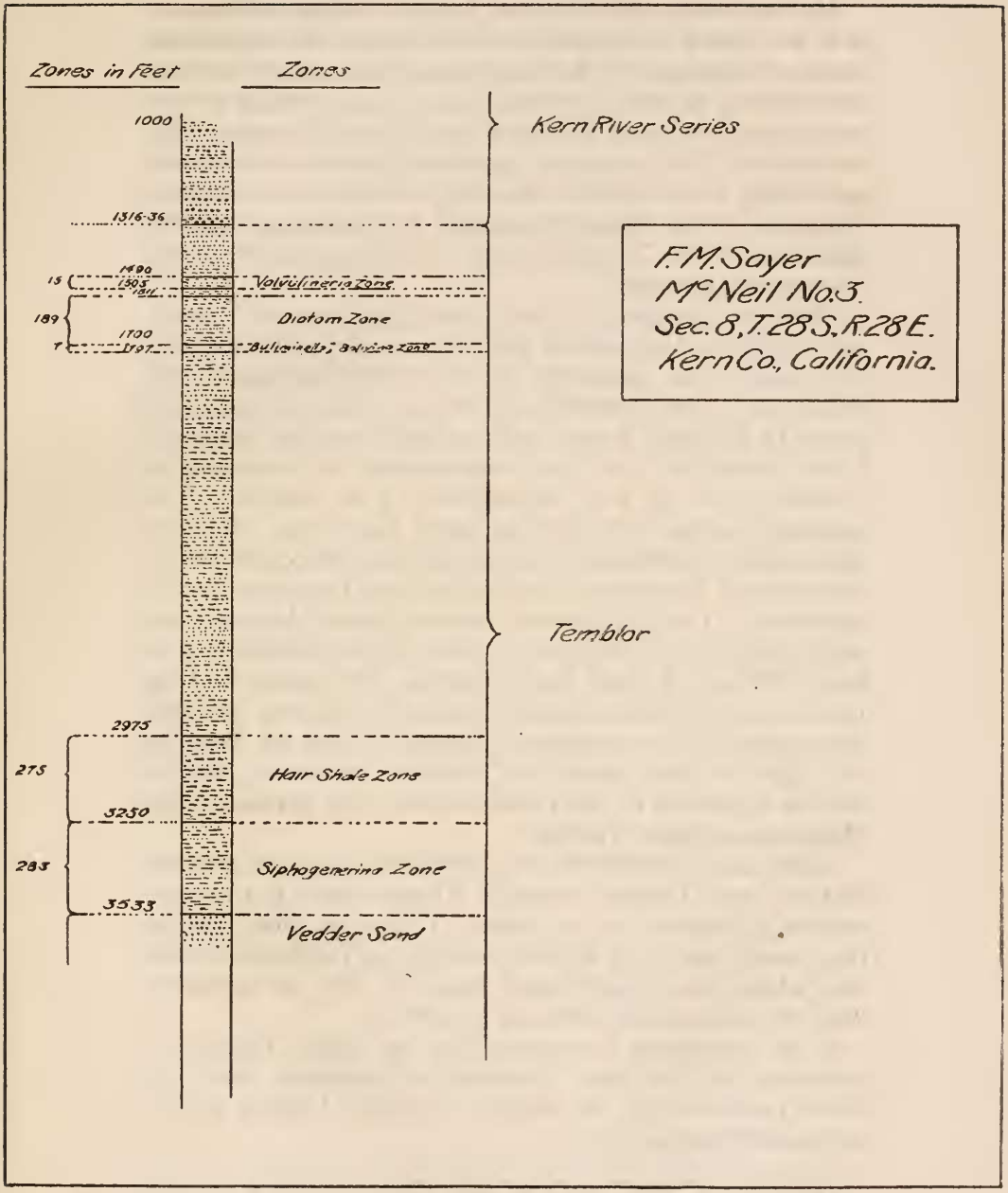

Fig. 3. Section shown in drilling F. M. Sayer Well, McNeil No. 3, near Sharktooth Hill.

My own study of the diatoms found in marine sediments a few feet below the stratum which yielded the mammalian remains investigated by Kellogg, indicate very clearly that this deposit must be very nearly the exact time equivalent of that portion of the Calvert formation which likewise contains fossil diatoms. The number of specialized species of short geologic range is too large for any other conclusion to be reached. Therefore if the Calvert formation be Tortonian then the upper part of the Temblor in the Kern River region should likewise be Tortonian.

Since the correlation of the Bowden beds with the Calvert and Temblor on the basis of mollusca was admittedly not positive there is the possibility that both may perhaps be the equivalent of the Helvetian of Europe. This has been suggested by Kellogg[18] from a study of certain marine mammals. I am inclined to favor this determination on stratigraphic grounds as well as from investigation of the diatoms. It is reasonably certain now that the upper part of the Monterey shale, widely distributed in California is the time equivalent of diatomites of Europe and Africa which have been placed in the Sarmatian. The time interval between upper Monterey and upper Temblor was sufficient to permit the accumulation of at least 5000 feet of thinly bedded shales. This seems too long for the two formations to be considered adjacent although there appears to be continuous deposition from the lower to the higher in many places in California. It seems plausible that the equivalent of the Tortonian may come between upper Monterey and upper Temblor.

Under any circumstances the conclusion seems unavoidable that the upper Temblor is middle Miocene; there is a preponderance of evidence to this effect. It may be added further that several species of diatoms occur in the California formation which have already been found in Italy in sediments definitely called middle Miocene by Forti.[19]

If the conclusion be correct that the upper Temblor is Helvetian and the upper Monterey is Sarmatian, the California equivalents of the standard European Miocene section conveniently fall as follows:

[18] Kellogg, R. Carnegie Inst. Washington, Publ. 346, art. 1, 1927, p. 5.

[19] Forti, A. Atti R. Inst. Veneto, Sci. Lett. Art. vol. 72, 1913, pp. 1535-1700, pls. 14-29.

Correlation of California and European Miocene

SECTION	EUROPEAN STAGES	CALIFORNIA FORMATIONS
Upper Miocene	Pontian	Santa Margarita
	Sarmatian	Upper Monterey
Middle Miocene	Tortonian	Lower Monterey
	Helvetian	Upper Temblor
Lower Miocene	Burdigalian	Lower Temblor (Pyramid Hill fauna)
	Aquitanian	Vaqueros